CONTRACT REPORT NO. OGT 84-00443

A MARKET EVALUATION FOR ELECTROSLAG CASTING (ESC)

A Report to
Canada Centre for Mineral and Energy Technology
(Contract File No. 03GT.23440-4-9262)

1984-12-05

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EXECUTIVE SUMMARY

Electroslag casting (ESC) is a process capable of producing steel and alloy castings with mechanical properties superior to those of cast products made by any other method. CANMET developed an expertise in ESC and built a laboratory ESC production unit in Ottawa suitable for prototype development. This market evaluation is preliminary to an effort to transfer CANMET's ESC technology to commercial units in the private sector.

There is no significant commercial base for ESC outside of the Soviet block of countries, where it is used in the manufacture of turbine rotors, large crank shafts, pressure vessels, and other items. ESC has been used in Japan to produce high-temperature alloy tubes and in Europe to produce rolling mill rolls. The process is nearly unknown in North America, where there are four small experimental facilities including that of CANMET.

The United States Department of Energy has identified ESC as a technology that may be necessary to produce equipment for coal gasification. DOE has engaged in a technology transfer program to stimulate and develop an industrial capability in ESC in the United States. Cameron Iron Works of Houston, Texas, has joined DOE in this technology transfer program.

Six possible target sectors in Canada were identified for CANMET's technology transfer program in ESC:

- o manufacturing high strength steel gears;
- o restoring worn rolling mill rolls;
- o manufacturing dies for forging, stamping, and die casting;
- o manufacturing high strength valves;
- o manufacturing products from difficult-to-forge alloys;
- o manufacturing heavy-wall pressure vessels.

The scope of each market, the benefits of ESC, the perceived impediments to adoption of ESC, and the most important potential Canadian participants from each sector for a technology transfer program are presented.

Five impediments that must be overcome in the technology transfer process were identified:

- o a general ignorance of the process;
- o no clearly perceived need;
- o a well-established forging industry (there is speculation that ESC was developed in the Soviet Union because that country lacked a comparable forging industry).
- o the perceived risk in the substitution of an unknown process;
- o the lack of western world precedent.

A technology transfer program is recommended to include a conference on ESC technology for potential targets, structured individual follow-up with delegates to the conference, negotiation of technology transfer agreements with selected companies, and publicity of the program and its results.

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A MARKET EVALUATION FOR ELECTROSLAG CASTING (ESC)

1 Introduction

1.1 Background

The Physical Metallurgy Research Laboratories (PMRL) of Canada Centre for Mineral and Energy Technology (CANMET) has developed the technology and a limited prototype capability to produce steel and alloy shaped articles by electroslag casting (ESC). [1,2,3] Electroslag casting is derived from the electroslag refining (ESR) process for producing ultra-clean ingots for use in high quality forgings, forging and extrusion dies, and other applications where normal impurities in the alloy would reduce the mechanical properties of the material to an unsatisfactory level for a particular application. CANMET and others have shown that electroslag castings are free from most of the usual defects found in castings made by traditional foundry methods and that their mechanical properties are similar to those of forged materials.

The ESC process has been described elsewhere and will not be described in this report.

CANMET is not alone in its interest in electroslag castings. The Department of Energy (DOE) in the United States has been investigating electroslag casting in its program to evaluate and develop materials for coal gasification plant components. Overall responsibility for the ESC project has been assigned to the DOE Morgantown Energy Technology Transfer Centre in Morgantown, WVa.

Implementation and technical management of the project is with the Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee.

There is no ESC industry in North America. ESC is used in the Soviet Union and other socialist countries for the production of critical components ranging from pressure vessels to high-temperature valves to large crank shafts for diesel marine engines, turbine rotors, and aircraft landing gear. [4,5] There is a significant ESR industry in North America, and ESR materials as well as Vacuum Arc Refined (VAR) materials are widely available.

CANMET perceives an opportunity for the transfer of ESC technology from its laboratories to the Canadian metalworking industry to enhance that industry's competitiveness in the international marketplace for high quality products in the machinery and equipment sectors.

Through the CANMET's Office of Technology Transfer, Thomas Shaffer Associates Inc. was retained as a consultant to describe and define the existing and potential market for ESC technology and to identify Canadian Companies that would be interested in cooperating with CANMET to demonstrate this technology.

1.2 Scope of the Project

CANMET asked the consultant to contact Dr. Alec Mitchell of the University of British Columbia and the US Department of Energy personnel associated with the ESC project in Morgantown and Oak Ridge and to determine the following:

1.2.1 the actual present consumption of electroslag products such as ESR ingots and ESC castings, nozzles, etc. in the US and Canada;

1.2.2 the percentage of the products consumed in 1.2.1 that is produced in the US and Canada;

1.2.3 the estimated potential ESC market in North America if ESC were to be actively implemented in North America as it is in Europe and Japan;

1.2.4 the portion of 1.2.3 that is the Canadian market, ie, the potential displacement of castings or forgings in Canada by ESC products;

1.2.5 the companies who have ESC or ESR experience in Canada on both the production and procurement sides;

1.2.6 the companies in the non-communist countries who practice ESC, eg, major steel producers, foundries, fabricators, or specialist ESC units, etc;

1.2.7 the perceived and actual impediments to ESC practice in the US and in Canada such as

- o lack of turnkey operations
- o lack of non-proprietary technology
- o low market demand
- o absence of ESC standards, specifications;

1.2.8 the Canadian company or companies who would be interested in cooperating with CANMET to

demonstrate ESC technology using, if necessary, PILP funding which requires a financial contribution from the company.

1.3 Procedure and Execution of the Project

The consultant reviewed some of the technical literature and met with R. Thomson, Scientific Authority for the project, and R. K. Buhr and G. Morin of PMRL to obtain essential background for the project. Other people contacted during the investigation are listed in Appendix A. The nature of each contact, that is, letter, telephone interview, or personal visit and interview, is indicated.

Early in the investigation, it became apparent that there was no statistical base for ESC in the western world and that some of the questions posed by CANMET could only be answered by conjecture. It also became apparent that there is no existing European or Japanese ESC industry on which to model a North American industry. ESC appears to be limited to very specific applications such as rolling-mill rolls and high-temperature alloy tubes. Reports of who practices ESC in the western world, other than in the production of rolls and alloy tubes, are inconsistent. Several people interviewed suggested that ESC technology, although first developed in the west, was implemented in the Soviet Union because that country lacked the well established forging industry that exists in the west.

Therefore, some time was invested in the identification of one or more niches that ESC could fill, and a strategic outline was developed to transfer ESC technology to Canadian firms in a position to fill these niches.

2 Supply of ESC and ESR Products in North America

2.1 Statistical Information

The only known source of statistical information on the production of electroslag products is AIS 10-V-3, "Electroslag Remelted Shipments," a quarterly report by the American Iron and Steel Institute. This report is confidential to the reporting companies. A copy of a recent report is attached, Appendix B. It should be noted that much of the data has been witheld from the report to avoid disclosure of proprietary information. According to the person who provided the copy, not all producers report their production, and the report is believed to represent less than half the total.

2.2 ESC Production

There is no commercial ESC production in North America.

Four experimental ESC production units are known to exist. They are located at CANMET in Ottawa, at the University of British Columbia in Vancouver, at Selectritech Corporation in Pittsburgh, Pennsylvania, and at Cameron Iron Works in Houston, Texas.

G. K. Baht of Selectritech Corporation is a strong promotor of ESC and offers equipment and technology to prospective producers. Baht claims to have two clients about to get into ESC with capacities of 6000 tonnes per year each. He did not identify the clients. Baht believes that ESC

capacity in the United States will be about 80,000 tonnes per year by the year 2000.

2.3 ESR Ingot Production

Eight companies are known to produce ESR ingots in the United States for sale to other companies or for further processing in their own facilities: Inco Huntington Alloys, Cabot Corporation, Lukins Steel, Car-Tech, Teledyne Al-Vac, National Forge, Republic Steel, and Latrobe Steel.

Total ESR production capacity in the United States is about 200,000 tonnes per year. Present utilization is believed to be between 50 and 70 percent. ESR materials include carbon and alloy steels, tool and die steels, stainless steels, high temperature materials, and electrical and electronic materials. High temperature materials make up about half the total production according to the data in the American Iron and Steel Institute report.

There is no ESR production in Canada.

2.3.1 Suppliers to the ESR Industry

Only one firm, Consarc, produces ESR furnaces in the United States. Laybolt-Hereaus and Bohler manufacture in Europe and export to the United States.

Foote Minerals is the leading supplier of slags and provides pre-fused materials of various compositions.

3 Demand for ESC and ESR Products in North America

According to the AISI report, ESR material is shipped as ingots, slabs and other primary shapes, wire and wire rod, plates, bars, tubing, sheet and strip, and other products. The report shows that of the total shipments during the first half of 1984, 59 percent was high temperature metals and 13 percent was stainless steel. Although there are no numbers, the report indicates that ESR alloy steels are shipped only as ingots, primary shapes, and bars. It is believed that most of the use of alloy steels is in forming and extrusion dies and in forging blanks.

Except for rolling mill rolls, it is believed that most ESR material consumed in North America is produced in the United States. ESR rolls are imported from R. B. Tennant, a division of Sheffield Forge Masters in the United Kingdom, from Cockerell and Gray in the UK, from Hitachi in Japan, and from OSB in Belgium. Some rolls have been produced in the United States from ESR ingots, but the US is not a major supplier.

Total consumption in North America of all ESR material exclusive of rolls is believed to be on the order of 90,000 to 100,000 tonnes per year.

There is no confirmed consumption of ESC products other than rolls in the United States or Canada. The Elliott Company in Jeanette, Pennsylvania, builds turbines. Some of Elliott's business is with the USSR, for which it is believed to manufacture and ship to Soviet markets in South America. There is speculation that Elliott may be incorporating some

ESC parts produced in the Soviet Union into the goods manufactured for the Soviets, but this could not be confirmed.

There were also reports that Babcock and Wilcox had used ESC to produce nozzles for pressure vessels. Detailed information could not be obtained from Babcock and Wilcox, but the consultant got the impression that electroslag welding had been used to attach preformed nozzles to pressure vessels at one time.

4 World Supply and Demand for ESC and ESR Products

4.1 ESC Products

Information on world supply and demand for ESC products is sketchy and inconsistent. Except for rolls, there do not appear to be any products regularly made by ESC technology, and some of the so-called ESC rolls are forged and machined from ESR ingots. Mitsubishi Heavy Industries used ESC to produce high-temperature alloy tubes for service in petrochemical and other processing industries. ESC was developed as a replacement for centrifugal casting of difficult-to-forge alloys. From 1968 to 1973, Mitsubishi reportedly cast more than 10 000 metres of alloy tubes. (6) The consultant has placed a request for updated information with Mitsubishi Canada, and this request has been forwarded to Mitsubishi Heavy Industries. A reply will be forthcoming and will be forwarded to CANMET.

G. K. Baht makes references to ESC production in Germany and Austria. However, he has not named companies, specific applications, or quantities involved.

Alec Mitchell believes that ESC is not being practiced outside the Soviet Block at this time except in the production of rolls. Mitchell confirmed that Mitsubishi has made high-temperature alloy tubes, but indicated that this was a special event and that it is not an ongoing commercial enterprise.

Some ESC products are being imported into Western Europe from the Soviet block. Pressure Vessels imported from Eastern Europe may have ESC nozzles. There is said to be a Lloyd's classification for ESC pressure vessels, which would indicate that there may be a substantial number of them in use.

Information presently available suggests that there is no established ESC industry in the western world and that the only use of ESC, other than rolls and a few specialty products such as the high-temperature alloy tubes made by Mitsubishi, is in products imported from Eastern Europe.

4.2 ESR Products

Western Europe, Japan, and the Soviet Union have well established ESR industries. Production capacity in Europe is believed to be about 100,000 tonnes per year. Japanese capacity is believed to be about the same, 100,000 tonnes per year. ESR capacity in the Soviet Union is believed to be in the order of 300,000 to 400,000 tonnes per year.

Sumitomo is reported to be casting titanium by the ESR method. According to Mark Hobday of the US Department of Energy and Rod Judkins of Oak Ridge National Laboratory, the

capacity is 3 to 4 tonnes per day. There is no evidence to suggest that Sumitomo is producing shaped castings.

5 The Department of Energy ESC Project in the United States

5.1 Materials for Coal Gasification Plants

Shortly after the 1973 oil crisis, the Department of Energy (DOE) in the United States began looking at processes to exploit alternate energy sources. One of these was recovery of oil from shale; another was coal gasification. Both required high temperatures and pressures in the operating equipment. DOE officials believed that the cost of this high-temperature, high-pressure equipment could be reduced with the use of electroslag casting techniques. As a result, DOE Advanced Research and Technology funded a study on ESC with G. K. Baht. Responsibility for the project was transferred to the Morgantown Energy Technology Centre, and the technical development management was assigned to Oak Ridge National Laboratory.

After the initial study by Baht, the DOE project has been concerned primarily with determining the properties of ESC products and with technology transfer to the private sector. Sample castings of various alloys have been prepared for their work by Alec Mitchell, by G. K. Baht, and by Cameron Iron Works.

DOE currently has a contract with Cameron for two step castings to determine the effect of the thickness of the casting on the mechanical properties, and for several small valve bodies to determine the viability of ESC for valves.

According to E. L. Raymond of Cameron, the valves will be small and will be cast to finished exterior shape. No attempt will be made to core the interior of the valve bodies.

The DOE project has attempted to identify the demand for ESC products so that it could encourage American industry to adopt ESC technology. It has been unable to develop any hard numbers. Except for the trials at Cameron Iron, it has been unable to secure any cooperative ventures in the private sector.

According to all the DOE people interviewed by the consultant, unless a firm cooperative venture comes along soon, funding for the DOE program on ESC will be dropped.

5.2 The ESC Program at Cameron Iron

Cameron Iron Works is a major supplier of well-head equipment for the oil and gas industry. Valves are a major business of Cameron Iron, and it has a major investment in casting and forging equipment. E. L. Raymond came to Cameron Iron with ESR experience and guided the company's cooperative venture with DOE. To date, Cameron Iron has made only a handful of step castings, and these were of questionable quality.

Alec Mitchell served as a consultant to Cameron, and much of their early equipment shows the influence of Mitchell. However, they are unable to use Mitchell's aluminum moulds because their ambient water temperature is too high.

As indicated above, Cameron is currently contracted to DOE to supply two more step castings and several small valve bodies. However, their self-interest does not appear to be in the manufacturing of ESC valves but in the use of ESC to produce forging dies. According to Raymond, large dies are extremely difficult to make, and the incidence of unacceptable defects in conventionally cast die blocks is too high. Cameron believes it can cast a die block by the ESC method, eliminate the unacceptable defects, and produce a near-net dimension die cavity all in one step. It's ultimate goal is to be able to cast dies weighing in excess of 500 kg.

5.3 Other Materials--Nickel Aluminide

The people at Oak Ridge National Laboratories who are working on the ESC project are also working with other high-temperature materials. One of these is nickel aluminide. By doping the basic Ni_3Al with boron and other elements, researchers at Oak Ridge have improved the ductility of the material to the extent that its use as a structural material is feasible.

Nickel aluminide develops very large grains during sand casting. The material can be cold worked, but because of its high strength, the power requirement is extremely high. Attempts to forge or otherwise hot-work the material have failed.

During the consultant's interview with Rod Judkins and Vinod Sikka at Oak Ridge, the possible use of ESC for aerospace applications came up, and the Oak Ridge people began to think about their problems with nickel aluminide. They speculated that electroslag remelting might produce a

better grain structure and enhance the mechanical properties of the material in the as-cast condition. If the properties were enhanced sufficiently, ESC might well be used to make high-strength components from nickel aluminide that could not be made any other way.

The consultant suggested that CANMET had the facilities and the technical expertise to carry out an electroslag remelting trial to produce material for testing. Judkins and Sikka responded favourably to the suggestion and welcomed the potential opportunity to work cooperatively with CANMET. The consultant agreed to report the idea to CANMET and to arrange for R. Thomson or his designee to call Judkins or Sikka.

It is recommended that CANMET exploit this opportunity for a cooperative program with Oak Ridge National Laboratory. The program will facilitate a new and mutually beneficial working relationship between Canadian and American government agencies with little or no political or diplomatic complication. It will enable CANMET to expand its own capability in ESC technology. It involves new potential applications for nickel, an important Canadian mineral commodity whose price has been depressed because of a surplus of supply over demand.

Oak Ridge has several sand-cast ingots in stock that could be used as electrodes. These are truncated cones about 45 cm long, 75 mm in diameter at the big end, and 50 mm in diameter at the small end. The ingots can be sent to Ottawa as soon as mutually agreeable arrangements have been made.

6 Potential Opportunities in Canada for ESC Products

Despite the absence of a going ESC industry in the western world, the evidence gathered in this investigation indicates that ESC fills a void in metalworking technology and that there is an opportunity for effective technology transfer in Canada. ESC yields a cast material virtually free of the defects normally found in castings. ESC is capable of yielding a shaped product with the mechanical properties of a forged product. ESC is capable of yielding a shaped product from any of several materials including those that cannot be hot-worked by forging. ESC is capable of producing a large die block with the die cavity cast to near-net shape. ESC is the only casting process in which the melting furnace and the mould are one and the same and in which the scrap rate is virtually zero.

Capital costs for ESC are relatively low in comparison with other casting and forging operations. Low capital cost would tend to discourage the establishment of a custom ESC industry because of the relative ease of entry. It is likely, therefore, that a successful ESC industry will comprise captive shops of various sizes, vertically integrated into manufacturing operations and making components for the parent company. Custom ESC business will likely be a small part of the total business.

The most probable opportunities for ESC in Canada are:

- manufacturing of high-strength ESC gears;
- restoration of rolling mill rolls;

- o ESC of superalloys and other difficult-to-forge materials for the aerospace and chemical processing industries;
- o ESC of dies for forging, stamping, and pressure die casting;
- o manufacturing of high-strength ESC valves;
- o heavy wall pressure vessels.

Each of these opportunities is discussed separately in the following sections. The scope of each market, the benefits of ESC, the perceived impediments to adoption of ESC, and the most important of the potential participants in any technology transfer to that sector are presented. These potential participants were not contacted by the consultant.

The limitations of the consulting contract do not permit a complete market analysis of any of these sectors.

6.1 Gears

Steel gears require high strength, good impact properties, and close dimensional tolerances. Forging is required to obtain the maximum mechanical properties, after which extensive machining is required. ESC would produce a gear with mechanical properties equivalent to a forged product and with less requirement for machining since it could be cast to near net shape. Pinion gears would likely be most easily and profitably produced by ESC.

The mechanical properties and reliability of ESC gears would have to be demonstrated to machinery builders and buyers to an extent that might verge on being ridiculous. A pinion gear represents a small part of the total capital cost

and an even smaller part of the operating cost of the machinery in the production of whatever product or service is involved. Failure of that gear would result in downtime, loss of production, and maintenance costs far in excess of the value of the gear. ESC is an unknown quantity, and the perceived risk of substituting a lower cost ESC gear for an existing satisfactory product would be a major impediment to the adoption of the process.

Major Canadian manufacturers of gears include Canada Forgings in Welland, Hamilton Gear and Machine Company in Toronto, and Spar Aerospace in Toronto.

6.2 Rolling Mill Rolls

ESC rolling mill rolls are commercially available from European manufacturers. The overall roll business in highly competitive. Stelco had seven roll suppliers in the late 1970's. Today, they have 38 suppliers. They are presently not using ESC or ESR rolls, but they have purchased them in the past from Tennant.

There are no Canadian suppliers of working rolls for rolling mills. Dominion Engineering in Montreal withdrew from the roll business early in 1984. Doloro Stellite in Belleville and Cru-Can Division of Slater Industries in Sorrel have also made rolls. Their current interest or activity in the business was not determined.

It is not suggested that Canadian manufacturers be encouraged to enter the competition for a share of the market for new rolls. However, there may be an opportunity for a Canadian company to carve out a niche in the renewal of used

rolls. According to Stelco, disposal of worn rolls is becoming a problem. Invariably, the only thing wrong with them is that their diameter has been reduced by wear and grinding to the point where they cannot be used for either work rolls or backup rolls.

There are two possible applications for ESC. The first is in the casting of a 50 mm or thicker layer of the appropriate iron or steel alloy onto old rolls. Some surface machining and extensive heat treatment would be required prior to casting. Electrodes would have to be small diameter rods or bars, and slip moulds would probably be necessary. The second opportunity is in the electroslag remelting of old rolls in moulds that would yield slightly smaller new rolls. Both applications would utilize old rolls. Whether either application would be economically attractive is not known.

Total cost in Canada for new rolls and rehardening of rolls is estimated at $30 million per year.

Rolls are bought and sold internationally, so it is likely that a Canadian firm with the capability to treat old rolls on a toll basis by the ESC process could develop a successful business in export as well as domestic accounts.

The application of ESC technology to roll restoration would require a substantial amount of technical development. The cost of this development without the assurance of a commercially viable process would be a significant impediment to any company adopting the technology. Roll making also requires a large capital investment in cranes and other materials handling equipment, heat-treating furnaces, and machining facilities. Only companies with prior experience

in the roll business could be expected to apply ESC technology successfully.

6.3 Difficult-to-Forge Materials

The production of high-temperature alloy tubes by Mitsubishi Heavy Industries is an example of using ESC to manufacture high-strength products from difficult-to-forge materials. The application of ESC to nickel aluminide is another. The scope of the project does not permit a thorough study of these difficult-to-forge materials or the products that could be made from them by ESC. However, these alloys represent one of the most likely areas where ESC could become commercially successful.

The principal applications of these difficult-to-forge materials will probably be in the aerospace industries, the synthetic fuel industries, and the petrochemical industries.

Eldorado Nuclear in Port Hope is looking for opportunities to diversify and has expressed an interest in specialty and difficult-to-work alloys. Spar Aerospace in Toronto and Fahramet in Orillia could also be interested in this type of application for ESC.

6.4 Dies

Die steels constitute a relatively small but very high value segment of the steel industry. The integrity of the steel, the mechanical properties, and the surface finish are critical. Forging dies require a high level of resistance to thermal fatigue as well.

The ESC process can satisfy these needs. It would enable a semi-finished die to be cast with the die cavity being already in place. It would eliminate the forging of the alloy steel ingot and the hogging out of the die cavity. It would not eliminate the finishing or heat-treating operations.

Machining of dies has become highly automated, and computer-aided design and manufacturing of dies has reduced their cost significantly. Whether ESC would lower the cost of die making further is not known.

Atlas Steels in Welland is the principal producer of die steels in Canada. Major die makers include Wentworth Mould and Die Company in Hamilton and SKD Manufacturing Company in Amhurstburg.

6.5 Valves

Forged valves represent a small segment of the total valve business in the chemical processing industries. Sand cast and shell moulded valves represent the vast majority.

The DOE program in the United States is largely concerned with the application of ESC technology to valve production. Valves are one of the specific items that Cameron Iron has been asked to make for the program. Unless it is the intention of CANMET to compete with the DOE program in the development of specific products, it is suggested that concentration on valves would be a duplication of effort at this early stage of the technology transfer process.

The DOE program notwithstanding, Canada has a fairly large business in cast valves. Esco in Port Hope, Fahramet in Orillia, and Canada Alloy Castings in Kitchener are the leading companies in cast valves. Velan Inc. in Montreal is the only firm known to be making forged valves. Velan's own production is limited to small sizes. Larger forged valves sold by Velan are manufactured by Cameron Iron and other firms outside Canada.

6.6 Heavy Wall Pressure Vessels

The recovery of hydrocarbons from sources other than crude oil, for example, coal and tar sands, requires the use of extremely high temperatures and high pressures. Pressure vessels may be well in excess of 15 cm thick, and are produced by narrow-gap welding techniques. The life of these vessels is limited by corrosion at the heat-affected zones adjacent to the welds. ESC could produce a pressure vessel with a completely homogeneous microstructure that would not be susceptible to corrosion at heat affected zones.

Canada supplies pressure vessels to the domestic and export markets. Versatile Vickers of Montreal is building two 300-tonne pressure vessels for the CANMET upgrader being installed at the Montreal refinery of Petro Canada and is actively seeking additional orders. The company recently lost in a competition with Japan Steel Works of Tokyo to provide a major vessel to Syncrude of Edmonton for the first phase of its $1.2 billion expansion project at Fort McMurray.

Other firms manufacturing pressure vessels in Canada include Combustion Engineering and Babcock and Wilcox.

Although Versatile Vickers' tender for the Syncrude vessel was reported to be from 20 to 50 percent higher than the Japanese tender, it is believed that the deciding factor may have been the track record of the Japanese vs. the relative inexperience of the Canadian firm and the perceived risk to Syncrude's operations. Syncrude purchased the pressure vessels in its existing plant from Japan when comparable vessels were being offered by Canadian manufacturers.

The track record of a supplier or of a particular type of equipment is exceedingly important in the purchase of major capital equipment. The absence of a track record for ESC pressure vessels in North America would be an impediment to its use because of this same perceived risk to the operation of a hydrocarbon recovery unit, nuclear reactor, or other process equipment. Unlike pinion gears, heavy wall pressure vessels are a significant part of the total capital cost of processing plants. Like pinion gears, their failure would result in costs to the operator through loss of production and maintenance that would far exceed the cost of the vessels themselves.

7 Impediments to the Transfer of ESC Technology

Despite the remarkable properties of ESC products and the apparent success of the process in the Soviet Union, there are several serious impediments to the transfer of ESC technology from the laboratory environment of CANMET to a profit-making commercial production unit. These impediments are:

- ignorance of the process;
- no clearly perceived need for the process
- the presence of a well-established and effective forging industry in North America;
- the perceived risk in substituting an unknown product for one that appears to be adequate;
- the lack of any significant western world precedent.

Some of these impediments can and must be removed during a technology transfer program. Others cannot be removed but must be considered in planning the technology transfer strategy.

7.1 Ignorance of the Process

Most executives in the metalworking industry know about electroslag welding and about electroslag refining of forging ingots. They know little if anything about electroslag casting of near-net-shape products and the properties of the castings. Because of this ignorance, there is no latent interest in the process to be stimulated.

The technology transfer process must include a well structured introductory educational component that will simultaneously inform and create interest.

7.2 No Perceived Need for ESC

ESC, in many ways, is a solution looking for a problem. Gear manufacturers, valve manufacturers, and die makers have nearly always been able to satisfy their customers with existing technology. They have successfully reduced their manufacturing costs through CAD/CAM programs and other innovations not involving new or different manufacturing processes. Except for the difficult-to-forge alloys, and to a lesser extent, rolling-mill rolls (as related by Stelco) and forging dies (as related by Cameron Iron), the market is not obviously seeking a new process that will do what ESC will do. There is no obvious and unequivocal target for the technology transfer.

The technology transfer process must initially address a relatively broad sample of companies so that their responses to the introductory educational component can be observed and the perceived need can be assessed for better targeting.

7.3 A Well-Established Forging Industry

There is some speculation that the widespread use of ESC in the Soviet Union resulted from the lack of an efficient forging industry in that country. Whether this is so or not, there is an efficient forging industry in North America. Forged products are well known, well understood, and widely used. Moreover, many of the manufacturers of products that could be made by the ESC process have substantial investments in forging equipment. An attempt to transfer ESC technology into traditional forging markets without significant and obvious economic and technical advantages would have little chance for success.

The technology transfer process must not target or appear to target markets for forgings in which there are no serious problems. ESC must complement, not compete with, forgings initially. With respect to the forging industry, difficult-to-forge alloys would be the best target.

7.4 The Perceived Risk of Substitution

Unless there is a problem, conventional wisdom in most industries says that one should maintain the status quo. Changing something that is not causing a problem--technical or economic--introduces risk. Most managers will not put an operation at risk unless the risk can be measured and the weighted potential benefits exceed the possible consequences. The substitution of an ESC component, whether it is a pinion gear or a pressure vessel, will be regarded as an introduction of risk.

The technology transfer process should initially target those applications where risk is minimal or where the potential benefits are very great relative to the risk.

7.5 The Lack of Western World Precedent in ESC

Most industrial executives don't want to be first to try anything new. There is comfort in being able to see that someone else has tried it and that it worked. There is very little precedent for ESC in the western world.

The technology transfer process should be supported by several thoroughly documented case histories describing the performance of Mitsubishi high-temperature alloy tubes and

any other ESC products including those that were imported into Western Europe from the Soviet Union. It is believed that Soviet case histories will have little impact on potential Canadian or American targets for ESC.

8 Recommended Technology Transfer Process

It is recommended that CANMET adopt a four-part program to transfer ESC technology to the Canadian manufacturing industry:

- Hold a conference on ESC technology and a demonstration of CANMET's capability in ESC for the leading potential participants from the six sectors described in Section 6.

- Carry out a planned and well structured individual follow-up with participants who express an interest in cooperating with CANMET in a technology transfer program and who, in the opinion of CANMET, can succeed in commercial implementation of the process.

- Negotiate a technology transfer agreement and appropriate cost-sharing arrangements with companies selected on the basis of criteria to be established by CANMET.

- Publicize the technology transfer program, the entry of the companies involved into ESC, and any successful applications in the trade and technical press.

8.1 Conference and Demonstration at CANMET

There is so little general understanding of ESC and its potential benefits that metalworking industry executives are unlikely to develop or express any interest in it for their own operations without some prior exposure, without a conviction of its benefits, and without confidence that ESC will not introduce unacceptable levels of risk to their successful businesses. For CANMET to achieve its technology transfer goal, it will have to generate this interest, conviction, and confidence through a well orchestrated demonstration of the process and its benefits.

A conference on ESC technology for key people in the industries most likely to benefit from it is the best vehicle for such a demonstration.

It is recommended that CANMET organize and convene a two-day conference for about 50 people. The program should comprise:

- a clear statement of CANMET's technology transfer objective and of its four-part program;
- the presentation of papers by the best North American authorities on ESC: R. Buhr, Alec Mitchell, G. K. Baht, and E. L. Raymond;
- a paper by someone from the Paton Electric Welding Institute in Kiev:

- a viewing of the film on Soviet ESC production, produced by Paton and available from Baht;
- a review of the DOE program in the United States by Rod Judkins, Vinod Sikka, or other DOE person;
- a demonstration of the ESC process at PMRL with the production of a real product such as a pinion gear;
- the presentation of generous segments of the ESC products made during (or before) the demonstration to the delegates for their own testing and analysis;
- a general tour of PMRL facilities;
- generous time allowance for questions and discussion;
- hospitality lunches and refreshment;

Attendance should be by invitation only and should include responsible executives of the leading companies in the six fields considered most likely to benefit from ESC. There should be no cost to the delegates other than their own time, transportation, and accommodation. CANMET should organize and provide transportation between the meeting site and PMRL for the ESC demonstration. Bound copies of the proceedings of the conference should be sent to all delegates within four weeks.

CANMET should expect to provide fees or honouraria and reimbursement for expenses to the speakers.

8.2 Individual Follow-up Conferences

Through a mail and telephone survey about six weeks after the conference, CANMET should determine which of the delegates has any interest in further pursuit of ESC technology. Those who express a credible interest should be visited and interviewed personally.

During each visit, the interviewer should determine the nature of the intended application, including the alloys involved, the size and other physical aspects, and the mechanical and chemical requirements. Some estimate of production quantities and the required physical plant should be made.

CANMET should analyze the data gathered by the interviewer and decide which of the interested parties, if any, should be invited to participate in a technology transfer program with cost-sharing arrangements. Criteria for this selection should be established by CANMET.

8.3 Technology Transfer and Funding Agreements

Companies determined by CANMET should be invited to participate in the technology-transfer program. Technical assistance and cost-sharing agreements would have to be negotiated with each of the participants. Any licensing of or royalties for existing intellectual property would have to be arranged at this time. Agreements would have to be negotiated on ownership and the rights to the use of new intellectual property developed during or as a result of the technology transfer program.

CANMET should retain the right to publicize each technology transfer agreement and the development of products resulting from it.

8.4 Publicity in the Technical and Trade Press

CANMET should systematically publicize each technology transfer agreement and the development of any products resulting from it in the appropriate technical and trade journals. CANMET should encourage the preparation and presentation of technical papers by the participants in the technology transfer program with co-authorship by CANMET scientists and with appropriate acknowledgement of the program.

9 Summary and Conclusion

Electroslag casting technology is capable of producing cast steel and alloy products with mechanical properties superior to those of cast products made by any other method. CANMET developed an expertise in ESC and built a laboratory ESC production unit suitable for prototype development. Thomas Shaffer Associates Inc. was retained to carry out a market study in preparation for the transfer of ESC technology to Canadian industry.

The consultant contacted the people in North America who are most informed about electroslag casting technology to determine the size and nature of existing markets for ESC products, to ascertain the potential market for ESC technology, to identify some of the impediments to the

adoption of ESC technology, and to learn what developments are already taking place in the commercialization of the process.

The study showed that there is no significant commercial base for ESC outside of the Soviet block of countries except for limited applications in Europe and Japan. The process is nearly unknown in North America, where there are four small experimental facilities including that of CANMET in Ottawa. High-temperature alloy tubes and rolling mill rolls have been produced by ESC in Japan and Europe, but with these exceptions, the only western experience with ESC has been the importation of products manufactured in the Soviet block.

It was not possible to determine the potential market for ESC in North America. The only estimate known to have been made is for an ESC production capacity of 80 000 tonnes per year in the United States by the year 2000.

The United States Department of Energy has identified ESC as a technology that may be necessary to produce equipment for coal gasification. Through the Morgantown Energy Technology Center and the Oak Ridge National Laboratory, DOE has engaged in a technology transfer program to stimulate and develop an industrial capability in ESC in the United States. To date, one company, Cameron Iron Works of Houston, Texas, has joined DOE in this technology transfer program.

Six areas are considered as likely targets for ESC technology transfer. They are gears, rolling mill rolls, difficult-to-forge materials, dies for forging, stamping, and

die casting, high-strength valves, and heavy wall pressure vessels.

Five impediments to technology transfer were identified. They are ignorance of the process, no clearly perceived need, a well-established forging industry, the perceived risk in substitution of unknown materials, and the lack of any western world precedent.

A four part technology program is recommended. The program includes a conference on ESC technology for the leading potential targets for technology transfer, a structured individual follow-up with the participants of the conference, negotiation of technology transfer agreements with selected companies, and publicity of the technology transfer program and its results.

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6. A. Ujiie, S. Sato, S. Sakai, and J. Nagata, "Development of New Dynamic Casting for Application of Cylindrical Products--Production of High Temperature Alloy Tube by Newly Developed 'YOZO' Technique," Proceedings 4th International Symposium on Electroslag Remelting Processes, Tokyo, June 7-8, 1973

APPENDIX A

PEOPLE CONTACTED DURING THE STUDY

	Letter	Phone	Visit
Dr. G. K. Baht, President Baht Technologies International 172 Boxfield Road Pittsburgh, PA 15241 (412) 835-9212 (412) 854-2341	*	*	*
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APPENDIX A (CONTINUED)

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APPENDIX A (CONTINUED)

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APPENDIX A (CONTINUED)

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APPENDIX A (CONTINUED)

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APPENDIX B

AIS 10-V-3 REPORT OF ELECTROSLAG REMELTED SHIPMENTS

NOT FOR PUBLICATION
INFORMATION FOR REPORTING COMPANIES ONLY

AMERICAN IRON AND STEEL INSTITUTE
1000 16th Street, N.W.
Washington, D.C. 20036

AIS 10-V-3

ELECTROSLAG REMELTED SHIPMENTS
(Report in Pounds)

SECOND QUARTER - 1984
Quarterly Period

BY TYPE OF PRODUCT	SHIPMENTS							
	TOTAL		CARBON STEEL		ALLOY STEEL		STAINLESS STEEL	
	Current Quarter	Year to date	Current Quarter	Year to date	Current Quarter	Year to date	Current Quarter	Year to date
ALLOYS FOR CASTINGS	-	-			-	-	-	-
INGOTS	1,170,755	2,543,420			D	D	-	-
BLOOMS, SLABS, BLTS, BH. BARS, TUBE RO	D	D			D	D	575,369	1,164,400
WIRE--RODS AND DRAWN COILS	194,128	375,088			-	-	-	D
PLATES	D	D			-	-	-	-
BARS--HOT ROLLED & COLD FINISHED	3,254,773	6,761,167			D	D	D	D
TUBING	D	D			-	-	-	-
SHEETS--HOT ROLLED & COLD ROLLED	1,949,902	3,647,846			-	-	D	D
STRIP--HOT ROLLED & COLD ROLLED	736,225	1,644,360			-	-	D	D
ALL OTHER PRODUCTS	D	D			-	-	-	-
GROSS SHIPMENTS	9,585,008	20919,520			D	D	1,472,271	2,794,514
LESS SHIPMENTS TO REPORTING COS.	151,000	309,355				-25,645	-	-
NET SHIPMENTS	9,434,008	20610,165			D	D	1,472,271	2,794,514

BY TYPE OF PRODUCT	SHIPMENTS							
	TOOL STEEL		HIGH TEMPERATURE METALS		ELECTRICAL AND ELECTRONIC METALS		ALL OTHER	
	Current Quarter	Year to date	Current Quarter	Year to date	Current Quarter	Year to date	Current Quarter	Year to date
ALLOYS FOR CASTINGS	-	-	-	-	-	-	-	-
INGOTS	-	-	D	D	-	-	D	D
BLOOMS, SLABS, BLTS, BH. BARS, TUBE RO	-	-	729,040	2,432,362	-	-	-	-
WIRE--RODS AND DRAWN COILS	-	-	D	D	-	-	D	D
PLATES	-	-	913,476	2,138,152	D	D	-	-
BARS--HOT ROLLED & COLD FINISHED	-	D	1,158,303	2,611,437	D	D	D	D
TUBING	-	-	D	D	-	-	D	D
SHEETS--HOT ROLLED & COLD ROLLED	-	-	1,889,111	3,474,245	D	D	D	D
STRIP--HOT ROLLED & COLD ROLLED	-	-	635,528	1,395,523	D	D	D	D
ALL OTHER PRODUCTS	-	-	-	-	-	-	D	D
GROSS SHIPMENTS	-	D	5,614,311	12313,558	D	D	D	D
LESS SHIPMENTS TO REPORTING COS	-	-	151,000	335,000				
NET SHIPMENTS	-	D	5,463,311	11978,558	D	D	D	D

D - Disclosure

8/21/84